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NAVY DEPARTMENT
BUREAU OF ENGINEERING

Report

on

Test of Model QB Underwater
Sound Equipment of the
U.S.S. CUTTLEFISH.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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AUTHORIZATION~~CONFIDENTIAL~~

1. The testing of this equipment was authorized by Bureau of Engineering confidential letter C-SSI71/S68(2-21-W6) of 3 July 1934.

OBJECT OF TEST

2. The object of the test was to determine the practical operating limits of the QB apparatus as installed on the CUTTLEFISH and to determine whether or not the apparatus meets the contract specifications, which are as follows:

- (a) Receiving the high frequency components of another submarine's propellers and/or machinery noises when such submarine is running submerged at a speed of 5 knots up to a range of 4000 yards when operated on a submarine submerged to 90 feet at a speed of 3 knots, both ships to be broadside to each other; moderate to smooth sea.
- (b) Obtaining echoes under above conditions at ranges of 4500 yards and automatically indicating the range up to 600 yards.
- (c) Obtaining echo soundings (white light) up to 1500 fathoms under normal ship operating conditions and automatically indicating the soundings (red light) up to 250 fathoms.

ABSTRACT OF TEST

3. The sound equipment of the USS CUTTLEFISH, the testing of which forms the subject of this report, was constructed for the Bureau of Engineering by the Submarine Signal Company under developmental contract NOs-32451. Test results show its operating limits for three purposes -- depth sounding, propeller sound detection and echo detection -- to be as follows:

(a) Depth Sounding (Fathoms):

<u>Operation</u>	<u>Required Performance</u>	<u>Actual Performance</u>
Minimum by Red Flash	—	1.5
Maximum by Red Flash	250	150.
Maximum by White Light	1500	900.

(b) Propeller Detection (Yards):

4000	1300.
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(c) Echo Detection (Yards):

Maximum Red Flash	600	800
Maximum Phones	4500	2750

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CONCLUSIONS

(a) The test results show that the QB sound equipment on the USS CUTTLEFISH fails to give the performance limits called for in the contract.

(b) In the case of soundings, it is of no great importance whether or not the maximum limits called for are rigorously met. The device is a good depth finder within its range and will serve the ship fairly well for this purpose. Recommendation as to the acceptance of the apparatus is not based on its depth-sounding performance.

(c) The value of the QB apparatus is primarily determined by its effectiveness for purely military purposes. Its depth sounding feature is of the nature of a by-product. There are plenty of other devices that are cheaper and simpler that will determine depths better than this apparatus. Its most important function, when installed on a submarine, is to detect propeller sounds to as great a range as possible and accurately determine their direction. Its next most important function is to give a sharp, clear echo from the target's hull to ranges approximately as great as it can detect propeller sounds and thus serve as a range finder. A failure in either one of these last two functions defeats the purpose of the apparatus. The tests show that the apparatus in question fails to meet the requirements for both of these uses, giving about 60 percent of the echo range called for i.e. for its second most important use, and 29 percent of the propeller detection range called for, i.e., for its most important use.

(d) As it stands, this apparatus is of practically no military value to a submarine because of its lack of ability to detect propeller sounds. It is weak as an echo detector, it is true, but no matter if it exceeded the performance requirements in this respect, it would still be of doubtful value on a submarine for the reason that the submarine cannot well employ echo detection of the target because of the danger of thus exposing her presence and location.

(e) It should be stated that during about 24 hours continuous use the subject apparatus operated without failure of any kind. All parts of the equipment are mechanically well constructed. There is no question but that the Submarine Signal Company has made an honest effort to fulfill its contract to the best of its ability.

RECOMMENDATIONS

It is therefore recommended that the QB sound equipment tested be not accepted until its performance has been materially improved for the following two reasons:

(a) The performance limits are reasonable, with the exception that those for propeller detection should be increased by 50 percent, and call for no more than a contracting company should meet if it is qualified to supply the future needs of the Navy for such apparatus.

(b) The effectiveness of our two newest submarines will be materially lowered and our sound developmental program, both in the Fleet and at this Laboratory, will be jeopardized if the QB equipment in its present state is left as a permanent installation on the CUTTLEFISH and CACHALOT.

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DESCRIPTION OF MATERIAL UNDER TEST

4. The QB apparatus is both a transmitter and receiver of high pitched sounds. It operates through the medium of rochelle salt crystals which, through their piezo electric properties, serve to generate sound when stimulated by a high frequency alternating current and serve to generate a varying electric-potential when they are exposed to oncoming sound waves. The high frequency alternating current supplied to the crystals when they are used for generating sound signals is supplied by modern radio power tubes with properly designed associated circuits. For reception of sound, the small voltages generated by the crystals are amplified to the point where they may serve to energize phones or to operate an indicating device.

METHOD OF TEST

5. The apparatus was tested to determine its practical operating limits for the three uses:

- (a) Detecting propeller sounds.
- (b) Echo detection of another submerged submarine.
- (c) Measurement of depth by flash (red light) and by phones (white light).

Following is an outline of the test procedure prepared by this Laboratory although some slight modifications were later made with regard to maneuvering the ships.

TEST NUMBER I

(a) Purpose. To determine the range through which the apparatus gives reliable sounding data by indicator and by phones. Both maximum and minimum limits shall be determined.

(b) Procedure. Upon leaving the Washington Yard the apparatus shall be set and adjusted for depth measurement by **indicator and so operated** (except for short intervals employed for securing other specific information as outlined) while enroute to rendezvous with S-20 until maximum limits are passed.

A record sheet shall be kept giving the value of flash indicated depth at 15 minute intervals until the Capes are passed and from then on for each 10 fathoms increase in depth.

The data record shall also show the number of echoes per signal.

The data record shall show minimum possible length of signal in terms of length of flash on the indicator scale before the sounding record is started and from then on the length of signal required to give reliable soundings for 10 fathoms and for each increasing increment of ten fathoms up to 50 fathoms and from thence for each increment of 50 fathoms. Finally, when the ship has passed beyond the maximum sounding limits, the minimum possible signal length shall again be determined and

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recorded as at the start of the test.

Soundings beyond the limits of indicator, provided these limits are passed before meeting up with the S-20, will be taken through the use of phones and recorded on the sounding record sheet. This record must finally be extended to a depth of 1500 fathoms. The number of echoes heard per signal and the minimum signal length required for each succeeding increase of 100 fathoms should be recorded.

Note 1. The above tests are to be carried out under normal operations for the CUTTLEFISH. These conditions will be decided by the officer in command.

Note 2. If the CUTTLEFISH returns to Hampton Roads the above sounding schedule will be repeated in reverse order on the way in.

TEST NUMBER 11

(a) Purpose. To determine the range to which the propeller sounds of S-20 can be heard on the QB apparatus under the conditions stipulated in the manufacturer's contract, viz- both ships operating submerged at 90 feet and S-20 maintained at broadside bearing relative to S-20.

(b) Procedure. The complete test will involve three separate maneuvers as follows,- (1) CUTTLEFISH speed 3 knots and speed of S-20 also 3 knots; (2) CUTTLEFISH speed 3 knots and speed of S-20 5 knots; (3) CUTTLEFISH speed 5 knots and speed of S-20 also 5 knots.

Maneuver 1.

CUTTLEFISH and S-20 submerge and proceed on parallel courses separated by 500 yards. If propeller sounds of S-20 are clear and distinct CUTTLEFISH will take diverging course at proper speed to keep broadside bearing relative to S-20 thus increasing the range by 500 yards. She will then change course to parallelism with S-20, resume original speed of three knots and listen again for propeller sounds of S-20. This procedure will be repeated until the limiting practical range of detection is reached and determined.

Note: The limiting practical range so determined should be well within the echo range of the QB and the range can probably be checked by echo. It will be possible to notify S-20 when this maneuver is completed by code sent from the QB of the CUTTLEFISH and received on the JK of the S-20. Such one-way communication can probably be employed to all ranges encountered in carrying out the whole test program.

Maneuver 2.

1. CUTTLEFISH and S-20 submerge to 90 feet and proceed in column on fixed course at three knots, separation 200 yards, until CUTTLEFISH signals S-20 to start test. Upon such signal CUTTLEFISH takes new course diverging 37 degrees from course of S-20 and continues at same speed of 3 knots while the S-20 will hold her original course but

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change speed to 5 knots.

2. Under these conditions the bearing of S-20 relative to CUTTLEFISH will remain fixed at 90 or 270 and the rate of separation will equal 4 knots. Thus the limiting practical range to which the propeller sounds of the S-20 can be heard will be given through the time elapsed between starting the run and loosing the propeller sounds of S-20. This maneuver must determine such time intervals.

3. During the above run S-20 will keep her JK manned and directed on the CUTTLEFISH. The bearing will continue fixed at 37 degrees abaft the beam. Upon receiving a prearranged signal from the CUTTLEFISH, transmitted on the QB, S-20 will change course 74 degrees toward course of CUTTLEFISH thereby making the two courses converge by 37 degrees. CUTTLEFISH will determine the time when propeller sounds of S-20 are definitely picked up and then signal S-20 surface. The range of the S-20 from CUTTLEFISH at that time can be computed from the data at hand. It should not differ greatly from that obtaining when the propeller sounds were lost. The average of the two ranges will be considered the practical working range.

Maneuver 3.

This maneuver will be executed identically the same as maneuver (1) except that the working speed for both ships is 5 knots instead of 3 knots.

TEST NUMBER III

(a) Purpose. To determine the limiting practical range to which the CUTTLEFISH can detect the S-20 by echoes directed broadside to hull when both ships are submerged to 90 feet and proceeding on parallel courses.

(b) Procedure. The complete test will involve two separate maneuvers as follows: (1) CUTTLEFISH speed 3 knots and S-20 speed 5 knots, and (2) CUTTLEFISH speed 5 knots and S-20 speed 5 knots.

Maneuver 1.

CUTTLEFISH submerge to 90 feet and proceed on fixed course at 3 knots - S-20 submerge to 90 feet 1000 yards astern of CUTTLEFISH and proceed at 5 knots on parallel course separated by 2500 yards from that of the CUTTLEFISH. S-20 will proceed on course for 10 minutes after passing CUTTLEFISH - Time of passing to be determined by use of her JK apparatus - then turn and come back over the same course and continue this procedure until notified that maneuver (1) is completed. If the echoes received by the CUTTLEFISH are clear and distinct she will reverse her course 180 degrees so as to increase the distance between the courses of the two ships by 500 yards. This procedure will be continued until the limiting echo range is reached.

Maneuver 2.

Both ships submerge abreast at range 2500 yards and proceed on parallel courses at 5 knots. If echoes are clear and distinct then,

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upon predetermined signal from CUTTLEFISH, each ship will shift course 30 degrees outward from that of the other ship, proceed for 3 minutes on this course and then shift back to the original course. This procedure will be repeated until limiting echo range is determined.

DATA RECORDED DURING TEST

6. The following is the data obtained during the tests.

TEST I
Sounding enroute to rendezvous

Time	Depth	No. of Echoes	Min. Signal Length	Remarks
0845	4	1	(1.75 fathoms	Speed 13 knots
0900	7.5	1	(2.	2 fathom sig. used.
0915	3.5	1	2.	
0930	5	1	2.	
0945	2.5	1	1.5 By detuning can make signal length about 1 fathom.
1000	2.25	1	2	
1015	2.75	1	2	
1030	2.5	1	2	Used 2 fathom - the shortest when tuned.
1045	1.25	1	1	Questionable
1100	1.5	1	1	"
1115	3	1	2	
1130	3	1	2	
1145	2.5	1	2-	Questionable
1200	6.5	1	2	
1215	3.5	1	2	
1230	4	1	2	
1245	2.5	1	2	
1300	4	1	2	
1315	2.25	1	2	
1330	2.5	1	2	
1345	8	1	2	
1400	6	1	2	
1415	6	1	2	
1430	5	1	2	
1445	6.5	1	2	
1500	5	1	2	
1515	5	1	2	
1530	20	2 to 3	2	Ship stopped dead
1545	15.5	1	2	Ahead at 13 knots
1600	9.5	2	2	Underway 6 knots
1615	-	-	-	C-2 submerged to get preliminary trim. SubSigCo engineers tested the horizontal head of QB.
1730	-	-	-	
1745	5.5	1	2	Underway-surface-13 knots
1800	5	1	2	
1815	4.5	1	2	
1830	5	1	2	

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<u>Time</u>	<u>Depth</u>	<u>No. of Echoes</u>	<u>Min. Signal Length</u>	<u>Remarks</u>
1845	-	-	-	Secured alongside S-20
2130	-	-	-	planning movements for tests
2200	7	1	2	Surface 13 knots
2230	7	1	?	
2300	10	1	?	
2400	13	1	-	
0030	13	1	-	
0130	16	1	-	

The watch was broken at this point and records were not kept, but Dr. Hayes and Mr. Clement followed the operation through until the echoes failed at about 150 fathoms. Beyond this point the depth increased rapidly and the soundings were carried on by the "white light" method to between 800 and 900 fathoms. Beyond this depth occasional echoes were heard and at 1450 fathoms Lieutenant Shea decided that about one echo out of six signals could be heard.

TEST II

Determination of maximum range for propeller detection

(a) Both ships 3 knots at 90 feet submergence.

<u>Time</u>	<u>Bearing of S-20</u>	<u>Range</u>	<u>Remarks</u>
1040	300	1200 yds	Cannot be heard.
1047	295	870	Not heard with certainty.
1100	Surface at range 1030 yds.		

Estimated range 750 yds.

(b) CUTTLEFISH 3 knots, S-20 at 5 knots. Submergence 90 feet.

<u>Time</u>	<u>Bearing</u>	<u>Range</u>	<u>Remarks</u>
1246	281	860 yds.	
1251(?)	285	1030 "	
1255(?)	288	1400 "	Propellers lost on way out
1257	300	1450 "	S-20 reversed course at this range.
1259	298	1150 "	First picked up propeller sounds.

Average propeller range 1300 yds.

(c) Both ships at 5 knots - submergence 90 feet.

Started at range of about 600 yards. Results very ragged. Propeller sounds could not be heard at 1320 yards or at 1270 yards. Range estimated as 1200 yards.

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TEST III
Echo Detection Range

(a) C-2 at 3 knots, S-20 at 5 knots. Submergence 90 feet.

<u>Time</u>	<u>Bearing</u>	<u>Range</u>	<u>Remarks</u>
1321	269	<u>2780</u>	Very weak but quite clear.
1326	274	<u>2600</u>	" " " " "
1331	277	<u>3300</u>	Echoes lost.

Average range 2750 feet

(b) Both ships 5 knots. Submergence 90 feet.

<u>Time</u>	<u>Bearing</u>	<u>Range</u>	<u>Remarks</u>
1438	273	<u>2800</u>	Weak but quite clear.
1448	273	<u>3400</u>	Echoes lost.

Estimated range 3000 yards.

DISCUSSION OF PROBABLE ERRORS

7. The performance limits arrived at from the tests recorded above should not be regarded as rigorously definite. The same tests conducted under different sea conditions and with different operators would give somewhat different results. The probability is that smaller ranges than those herein recorded would in general be obtained for the reason that the sea conditions throughout these tests were excellent, and the operator, Chief Radioman Harpster, is one of the very best in the Service. Moreover, the results obtained in Tests II and III were taken under the favorable condition where the direction of the target is known. The conditions afforded by the CUTTLEFISH were also unusually favorable. Plenty of time was permitted for securing perfect trim and the operation of the diving rudders was reduced to a minimum, so the local disturbances were reduced to a minimum. It is estimated that the ranges reported are from 10 to 20 percent above the reliable ranges that would be given under normal service operating conditions where the direction and range of the target is wholly unknown.

8. The above test results were discussed, and in general agreed upon by Lieutenant Shea, representative of the Bureau of Engineering, Mr. Clement of the Submarine Signal Company, and Dr. Hayes. There was not complete agreement on the meaning of "echo sounding" to 1500 fathoms. If the depth is determined by listening to the echoes on phones and observing where the white light is on the scale at the instant the echoes are heard, then it is this Laboratory's experience that at least 75 percent of the echoes must be heard to make the method effective. On this assumption, the maximum range lay between 800 and 900 yards. If it means the maximum range to which an occasional echo can be heard, then the limit should be about 1500. But under such conditions a stop watch serves much better than the white light, for it does not involve a determination of the whole number of turns made by the indicator arm between signal and echo. Such a determination becomes troublesome when

only an occasional echo returns.

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9. The specifications set the performance limits for depth sounding as those to be given under normal operating conditions. Lieut. Commander Styer interpreted this to mean normal cruising speed. For the CUTTLEFISH this is from 13 to 14 knots. The tests were made at such speeds.

RESULTS OF TESTS

10. The ratio of actual performance to required performance proved as follows:

- | | |
|-----------------------------------|-------|
| (a) Detection of propeller sounds | - 29% |
| (b) Echo detection | - 61% |
| (c) Depth sounding | - 60% |

11. Since the apparatus fails to meet the required performance by so great a margin, the question naturally arises as to whether or not the performance limits called for by the Bureau of Engineering are reasonable.

12. In the case of the range of 4500 yards for echoes -- this is about the limiting range for the QA apparatus under the favorable conditions stipulated for the subject tests and the QBX apparatus has given ranges greater than this under distinctly less favorable conditions. Therefore, an echo range of 4500 yards under the favorable conditions stipulated is not unreasonable.

13. The limiting range of 4000 yards on propeller sounds under the stipulated conditions may be regarded as unreasonable. The JK apparatus, which the QB replaces, consistently gives ranges of 5000 to 6000 yards under less favorable conditions, and the QB should have been required to give at least these ranges, otherwise it would make the sound equipment of a submarine less instead of more effective when installed in place of the JK. The unreasonable limit of 4000 yards, however, favors the contractor. If proper performance limits are taken for propeller detection, the percentage performance of the apparatus in question for propeller sound detection would be something like 22.5 instead of 29.

CONCLUSIONS

14. The test results show that the QB sound equipment on the USS CUTTLEFISH fails to give the performance limits called for in the contract.

15. In the case of soundings, it is of no great importance whether or not the maximum limits called for are rigorously met. The device is a good depth finder within its range and will serve the ship fairly well for this purpose. Recommendation as to the acceptance of the apparatus is not based on its depth-sounding performance.

16. The value of the QB apparatus is primarily determined by its effectiveness for purely military purposes. Its depth sounding

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17. As it stands, this apparatus is of practically no military value to a submarine because of its lack of ability to detect propeller sounds. It is weak as an echo detector, it is true, but no matter if it exceeded the performance requirements in this respect, it would still be of doubtful value on a submarine for the reason that the submarine cannot well employ echo detection of the target because of the danger of thus exposing her presence and location.

18. It should be stated that during about 24 hours continuous use the subject apparatus operated without failure of any kind. All parts of the equipment are mechanically well constructed. There is no question but that the Submarine Signal Company has made an honest effort to fulfill its contract to the best of its ability.

RECOMMENDATIONS

19. It is therefore recommended that the QB sound equipment tested be not accepted until its performance has been materially improved for the following two reasons:

- (a) The presence limits are reasonable, with the exception that those for propeller detection should be increased by 50 percent, and call for no more than a contracting company should meet if it is qualified to supply the future needs of the Navy for such apparatus.
- (b) The effectiveness of our two newest submarines will be materially lowered and our sound developmental program, both in the Fleet and at this Laboratory, will be jeopardized if the QB equipment in its present state is left as a permanent installation on the CUTTLEFISH and CACHALOT.